The aerosol particle size distribution in the uranium mine Rožná I, Czech Republic

H. Malá, P. Rulík, J. Hůlka, V. Bečková

National Radiation Protection Institute (SURO), Bartoškova 28, Prague 4, 140 00, Czech Republic

Abstract. Size distributions of aerosol particles containing uranium and its daughter products in the working environment of the uranium mine Rožná I (Czech Republic) in dependence on conditions in the mine and the ore mill are presented in this paper. The samplings were carried out by 6 stage cascade impactors repeatedly placed at three sampling locations - the working face, the crushing plant and the end of the ore chute. The arithmetic mean of activity medians of aerodynamic diameter for all sampling sites was about 7 µm. The ratio of the activity concentration of the radon daughter products (^{214}Bi, ^{214}Pb) to the ^{226}Ra ranged typically between 0.5 - 0.6, i.e. the mean value of radon emanation coefficient was higher than 0.40.

1. INTRODUCTION

The inhalation of the long-lived alpha emitting radionuclides most contributes to the dose of uranium miners. The radiological importance of the radioactive aerosol particles depends not only on the kind of radionuclide and its chemical form but also on the aerodynamic properties of the particles, mainly on their size [1], [3].

Our aim was to determine size distribution of aerosol particles containing uranium and its daughter products in the working environment of the uranium mine Rožná I (Czech Republic) in dependence on conditions in the mine and the ore mill.

2. METHODS AND EQUIPMENT

The samplings were carried out by 6 stage cascade impactors (KI) on collection substrates placed on individual stages and on the back-up filter (glass fibre filter). Gamma spectrometric analysis with HPGe detectors (15 - 100%) was performed to determine the activities of radionuclides on each collection substrate from individual stages and on the back-up filter. The results were used to evaluate the particle size distribution for individual radionuclides in terms of the activity median aerodynamic diameter (AMAD) and its geometric standard deviation (GSD) on the assumption of log-normal distribution of the data in agreement with [2].

3. AEROSOL SAMPLINGS AND MEASUREMENT

The samplings were carried out in the uranium mine Rožná I, the last working uranium mine in the Czech Republic. The ore is mined from the depth up to 1200m. After considering all the criteria for sampling (availability,

representativeness of samples, the estimated burden for miners) three sampling locations, in which the impactors were repeatedly placed, were selected. These are the working face, the crushing plant and the end of the ore chute. The description of the sites is given in table 1.

Table 1. The sampling locations

	Description of sampling site
Working face	W.f. is the collection site on the working face during the removal of the ore by men. The ore is mined at 14 workings simultaneously.
Crushing plant	Place where the ore is crushed and screened. The ore is moved by 2 belt conveyors into grinders. The operator sits several meters off the conveyor belts. The ore from 14 workings comes to the belts in the crusher building.
End of the ore chute	Sampling under the shaft where the ore is poured into containers. It is a place where carts are loaded with the ore via a chute.

When it was possible, the equipment was placed near the working people, in such position that it did not interfere with their work.

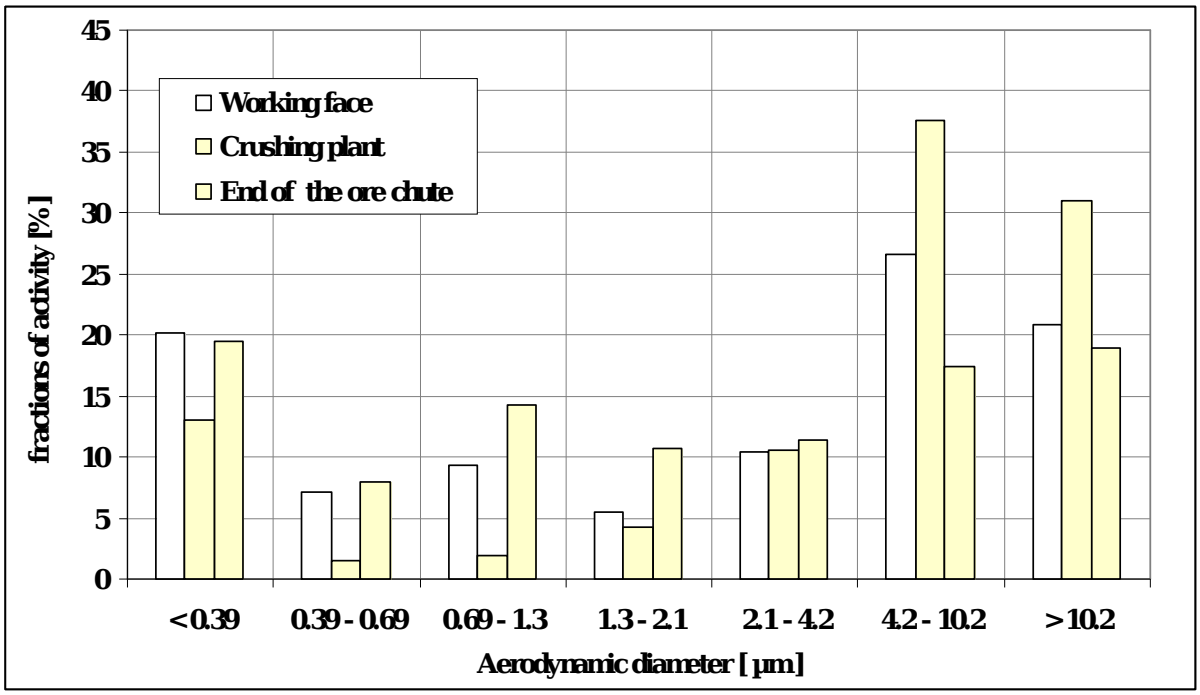
On the whole 18 samplings were performed at these three sampling sites within 2 years (2009, 2010). Swipes from the inner surfaces of the impactors were taken to estimate the interstage losses. The semiconductor gamma spectrometry was used to determine the activity deposited on the collection substrates. The measurement times were in the range of 80-500 thousand seconds. The obtained spectra contained a variety of natural radionuclides. For determination of the size distribution of aerosol particles ^{226}Ra (186 keV) was selected as a representative of the uranium series, because it was counted with the smallest uncertainty in most cases. In order to estimate the radon emanation from the aerosols activity concentrations of ^{214}Bi and ^{214}Pb were determined.

4. RESULTS AND CONCLUSIONS

The total activity concentrations of ^{226}Ra were in the order of magnitude 7×10^{-3} – 1.1×10^{-1} Bq/m^3. The character of most distributions (of all samplings) was similar. The biggest part of activity was attached to the particles with large aerodynamic diameters (AD > 4.2 μm), the minimum was at the size interval 0.39 – 0.69 μm. The highest proportion of large aerodynamic diameters was found at the crushing plant, which was probably due to the fact that coarse aerosol was constantly whirled and introduced into environment by crushing. The aerosol with AD > 10 μm contained more than 25% of the activity; in the crushing plant the share was over 30%. Aerosol particles with AD > 4 μm contained more than 55% of the activity, in the crushing plant it was almost 70%.

The data were evaluated assuming a log-normal distribution of activities in dependence on the aerodynamic diameter of aerosols. The parameters of the distribution were determined. Activity median aerodynamic diameter (AMAD) and geometric standard deviation (GSD) were estimated from the parameters of supposed distribution. The distributions were slightly bimodal with the boundary between modes lying around 0.4 μm and so AMAD and GSD were estimated excluding the smallest fraction of particles captured on a back-up filter. Results are shown in the figure 1.

Figure 1. The mean fractions of the activity concentrations (in %) in the size intervals of the aerodynamic diameter (in μm) determined at individual sampling sites



The AMADs ranged from 2.0 to 9.2 μm and GSD from 2.1 to 4.0 μm except one value of the GSD 6.5 μm (from the working face), but this particular distribution could not be considered as log-normal. Most AMAD values were in the range of 5-9 μm and GSD slightly over 3 μm (AMAD and GSD without taking into account the finest particles collected on the back-up filter). The arithmetic mean for all sampling sites was about 7 μm.

The combined uncertainty of the AMADs consisted of the following errors and uncertainties: the flow rate and its stability during sampling, losses on the walls of the stages, rebounds of the dropped particles and removal of the already caught particles, gamma-spectrometric analysis. The total uncertainty of the AMADs was estimated as about 30%; (only in the case of 2 samplings at the working face and the end of the ore chute the total uncertainty increased to 50%).

The AMAD values correspond to coarse industrial aerosol generated from the "gross" human activities. The values agree well with [4] and [5].

The ratio of the activity concentration of the radon daughter products (^{214}Bi, ^{214}Pb) to the ^{226}Ra ranged usually between 0.5 - 0.6, i.e. the mean value of radon emanation coefficient was higher than 0.40.

Differences in radon emanation of individual size fractions were insignificant due to large dispersion of the data.

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